Bedforms and Mine Burial

Edith L. Gallagher
Biology Department
Franklin and Marshall College
PO Box 3003
Lancaster, PA 17604-3003
phone: (717) 291-4055 fax: (717) 358-4548 email: edith.gallagher@fandm.edu

Rob Holman
COAS-OSU
104 Ocean Admin Bldg
Corvallis, OR 97331-5503
phone: (541) 737-2914 fax: (541) 737-2064 email: holman@coas.oregonstate.edu

Grant Number: N00014-02-1-0140; N00014-01-1-0389
http://cil-www.coas.oregonstate.edu:8080

LONG-TERM GOAL

The goal of this work is to develop a predictive understanding of coastal bedforms and their effect on the burial of objects on the seafloor.

OBJECTIVES

The objective of the research is to develop a robust characterization of the growth of the bottom profile envelope (the range from minimum to maximum depth) in the nearshore, both in time and space, using existing data. The specific objectives are to develop

- a statistical understanding of the time evolution of the bottom profile envelope
- the likelihood of the bed elevation above envelope minimum i.e., the probability of burial
- a model for prediction of bed profile statistics and mine burial

APPROACH

The generation and migration of bedforms (ripples, megaripples and sand bars) on sandy bottoms in the nearshore (0-8 m water depths) provides a mechanism whereby objects on the seafloor can become buried. As a bedform migrates past a mine, the mine will fall to the low point of the bedform trough before subsequently being buried by the passage of the following bedform crest. The statistics of mine burial by bedforms can be determined by the statistics of bed variability and the time evolution of the bottom profile envelope. We define the bottom profile as $h(x, \tau)$, and the profile envelope as spanning from $h_{min}(x, \tau)$ to $h_{max}(x, \tau)$. The envelope has zero thickness at $\tau=0$ (eg, when mines are placed) and as bed features form and migrate the thickness of the envelope grows with time (Fig 1).

Existing data sets (eg, Fig 1a solid line) are being used to examine the effect of bedforms on the temporal variability of the bed profile envelope (Fig 2). (See Gallagher et al. 1998a, Gallagher et al. 1998b, Gallagher et al. 2003 and www.frf.usace.army.mil for more information on existing data sets.)

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **30 SEP 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**
4. TITLE AND SUBTITLE **Bedforms and Mine Burial**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Franklin and Marshall College,Biology Department,,PO Box 3003,,Lancaster,,PA,17604**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

In addition, the growth, statistics, and spatial distribution of the profile envelope likely will depend on the overlying wave and current fields. Thus, the existing field data are being used to investigate relationships between the bed envelope and the measured flow parameters (Fig 3).

When D_{max}, the maximum envelope thickness, exceeds W, the vertical scale of a mine, the mine can be buried. However, at any subsequent time, burial depends on the instantaneous elevation above envelope minimum, $D = h - h_{min}$. In other words, a mine that is buried by a bedform crest can be exposed in the following trough of a migrating bedform. Thus, the likelihood of burial after a set amount of time is being examined (Fig 4).

In addition to temporal likelihood of burial, the spatial distribution of bedforms and resulting spatial likelihood of burial will also be examined. Gallagher et al. (2003) have found that, although bedforms are ubiquitous in shallow water (depth < 4 m), their spatial distribution is patchy. The spatial patterns of megaripple patches and the morphology of the bedforms (they are negatively skewed with broad flat crests and deep narrow troughs, Fig 1) become important in determining the fraction of bed area for which D < W.

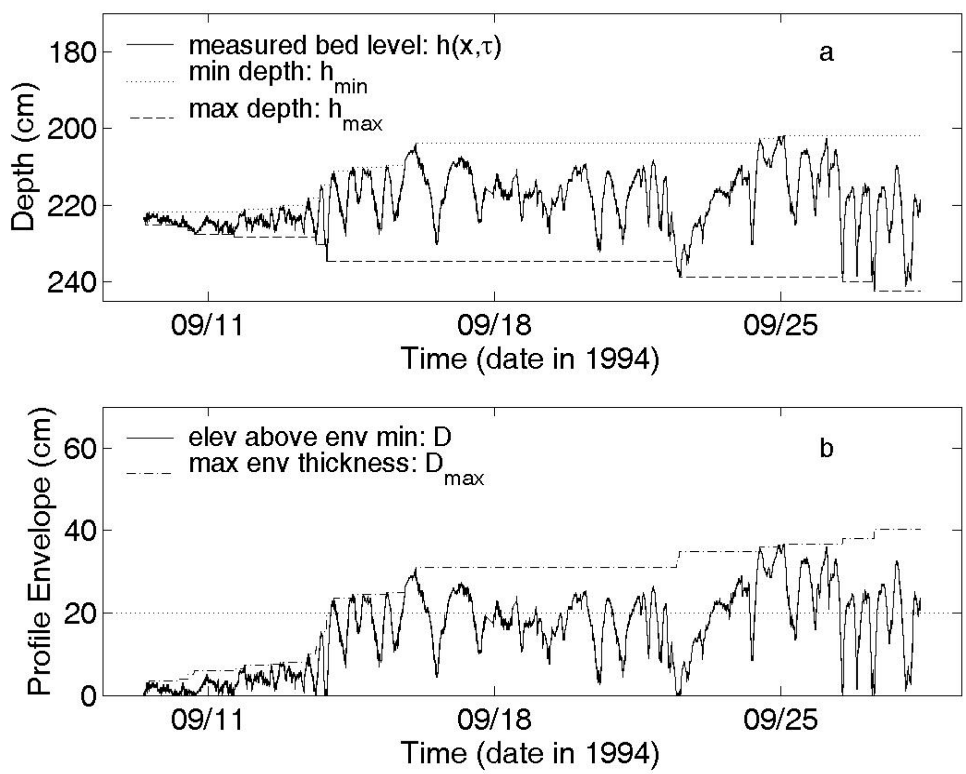

Figure 1: a) Example time series of bed elevation [with 20-30 cm amplitude fluctuations] from a stationary sonar altimeter in about 2 m water depth (solid line). The dashed and dotted lines represent the maximum and minimum depths reached during this time period. The maximum envelope thickness, D_{max} (dot-dashed line in b) is the difference between the dotted and dashed lines in a) [D_{max} slowly increases with time]. The solid line in b) is the instantaneous elevation above envelope minimum, D (from the solid line in 'a' minus the dashed line in 'a'). The dotted line in b) [constant at 20 cm] represents W, the vertical scale of a mine.

WORK COMPLETED

The maximum bottom profile envelope thickness, D_{max}, has been examined in water depths from 1.5 – 5 m using two months of data from eleven sonar altimeters during the Duck94 Nearshore Field Experiment. D_{max} was calculated for 4-, 6-, 8-, 10-, 12-, 14-, and 16-day windows (with 50% overlap). A histogram of D_{max} for the 6-day window is shown in Fig. 2a. Observed mean and standard deviation of D_{max} for each window is shown in Fig 2b as a function of time (or window length). The observed D_{max} has been shown to depend on normalized significant wave height, $H_{sig\text{-}norm}$ (measured in 8 m depth and normalized by the water depth at the sensor). The slopes of the best-fit line between $H_{sig\text{-}norm}$ and D_{max} are calculated and shown to change as a function of window length (Fig 3).

Results from the study of bed profile envelope characterization are discussed below and a manuscript describing that work is being prepared for publication. In addition, longer time series of bed level fluctuation (bipod data, FRF CRAB data) will be used to extend the statistics of bed envelope growth to include larger scale (erosion and accretion, sand bar migration) and seasonal changes.

Work is now underway to quantify the likelihood of burial of an object (as a function of both time and space). To do this, the instantaneous elevation of the bed above envelope minimum, D, at the end of a set time window (4, 6, 8, 10, 12, 14, and 16 days) is compared to a threshold elevation W (the vertical scale of a mine, here 20 cm is used, dotted line in Fig 1b). If $D>W$ then an object is buried and if $D<W$ then an object is exposed. Time windows are moved in 1 hr increments, thus hourly measures of “buried/not buried after X days” are obtained. Percent burial, P, is calculated as the number of buried observations divided by the total number of observations (Fig 4). Hourly estimates give over 1000 observations from one sensor for the 2 month-long experiment (there are 11 sensors).

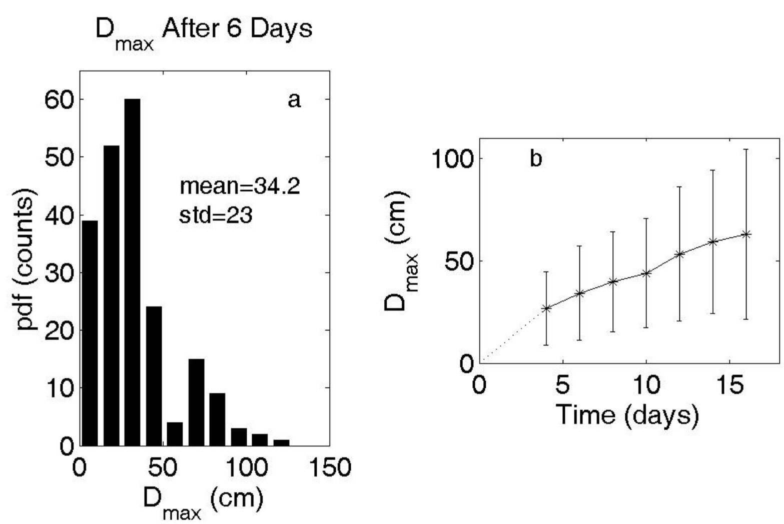

Figure 2. a) Histogram of envelope thickness for 6-day window. Two months of data were used, with τ=0 starting every 3 days (50% overlap) giving 19 estimates for each of 11 sensors. b) Mean and standard deviation of envelope thickness are plotted versus time [increasing monotonically from about 25 cm at 4 days to 62 cm at 16 days] (with window lengths of 4, 6, 8, 10, 12, 14, and 16 days, with 50% overlap, giving 29, 19, 14, 11, 9, 7, 6 estimates for each window). The dashed line is drawn to (0,0) since at τ=0 the envelope has zero thickness by definition.

RESULTS

The histogram of D_{max} after 6 days (Fig 2a) shows a peak at about 30 cm. This is in agreement with observations of megaripples, which have amplitudes of 10-50 cm. The second small peak between 60 and 80 cm corresponds to larger-scale changes in the morphology. This second peak existed, but was not as pronounced for the other data windows. The large standard deviations associated with the means (Fig 2b) are the result of using all observations for the two month period including both megaripples, which give D_{max} below about 50 cm, and larger-scale changes, which give D_{max} above about 50 cm. In the scatter plot of D_{max}, plotted versus $H_{sig-norm}$ in Figure 3a and b, a dotted line (at about 55 cm) suggests a separation between D_{max} owing to megaripples and D_{max} owing to larger-scale morphology changes. As expected, the larger D_{max}'s are associated with larger waves. When wave energy increases, more sand is moved and larger morphological changes take place.

It was proposed as part of this study that D_{max} would increase with time following an exponential taper (increase quickly at first and then taper off to a maximum or asymptotic value). D_{max} does increase with time (Fig 2b) but the exponential trend is not observed. By increasing the time over which D_{max} develops (by using longer time series and longer time windows), it is expected that this hypothesis will hold. The existing time series from sonar altimeters (only 2 months long) will be supplemented with other longer data sets (mentioned in the original proposal) to find the hypothesized asymptotic envelope maximum.

D_{max} has been compared with average normalized significant wave height, $H_{sig-norm}$ (Fig 3a and b). D_{max} and $H_{sig-norm}$ are positively correlated, where larger D_{max} calculated from larger morphological changes tends to be associated with larger waves. In addition, the slopes of the best fit lines between D_{max} and $H_{sig-norm}$ increases with time (window length) (Fig 3c). This finding indicates that the relationship between D_{max} and $H_{sig-norm}$ changes with time such that after 16 days a given $H_{sig-norm}$ gives a larger D_{max} than after 6 days.

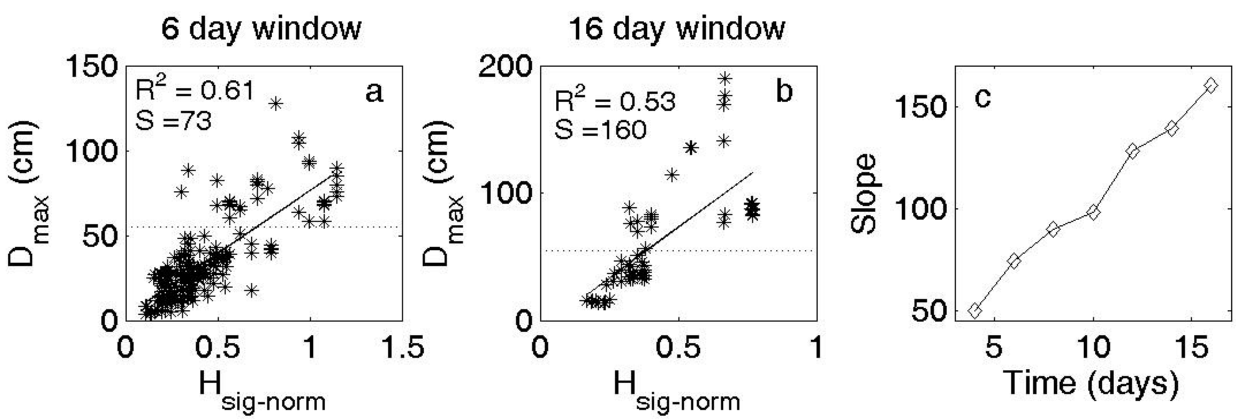

Figure 3. Maximum envelope thickness, D_{max} , after a) 6 and b) 16 days versus normalized significant wave height, $H_{sig-norm}$. [Scatter plots showing a positive correlation]. Solid lines are least squares best-fit lines to the data (asterisks). R and S are correlation coefficients and slopes of the best-fit lines. Dotted lines are to illustrate possible separation between megaripple-scale and bar-scale morphological variability. c)Slopes, S, of best-fit lines between D_{max} and $H_{sig-norm}$ versus time (see Table 1 for all data).

Table 1. Slopes and correlation coefficients of best-fit line between D_{max} and $H_{sig-norm}$ (see Fig 3).

window (days)	4	6	8	10	12	14	16
Slope, S	49	73	89	97	128	139	160
R^2	0.55	0.61	0.66	0.59	0.56	0.54	0.53

$H_{sig-norm}$ was averaged over the whole time window, thus conditions that do not contribute to the envelope growth could have a significant effect. For example, one large wave event during otherwise low wave conditions could generate erosion and therefore a large envelope, but the low waves would reduce the average wave height. This effect could make the best-fit line slopes anomolously steeper for longer time windows. Normalized maximum significant wave height, $H_{max-norm}$, during the time windows was also investigated to attempt to eliminate this averaging bias. Although the correlation coefficients were not as good for $H_{max-norm}$ as they are for $H_{sig-norm}$ (Table 1), an increase in best-fit line slopes with time was still observed. Further investigation of this effect will help elucidate a predictive relationship between waves and D_{max}. Various fluid parameters (mean, RMS, total near-bottom water velocity, etc.) calculated from current meters co-located with the altimeters were not as well correlated with D_{max} (not shown) as the offshore significant wave height.

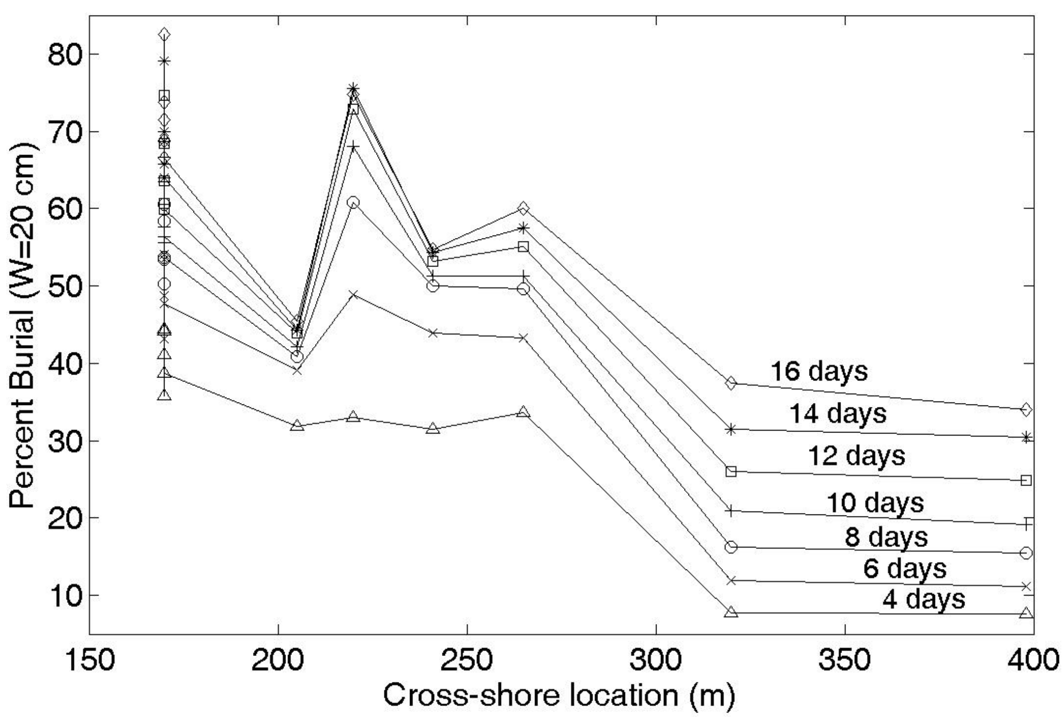

Figure 4. Percent burial versus cross-shore location and for each of the time windows. [P increases with time and increases in shallow water. In the surf zone, P=45-75% after only 8 days. Outside the surf zone, P=16% after 8 days and P=35% after 16 days.]

Percent burial, P, is calculated as the number of observations of burial after a set amount of time, divided by the total number of observations. Burial is observed when D > W at the end of the time window and it is estimated every hour, thus there are hourly observations of "buried/not buried after X days". P is observed to increase with time and P is higher shallow water.

As time goes by and waves work the sediments on the seafloor, megaripples are generated and migrate, erosion and accretion take place and both D_{max} (Fig 2b) and P increase (Fig 4). In the shallow water of the surf zone (x < 250 m in Fig 4) where waves break and currents are strong, more energy is available to move sediment and these morphological processes occur more quickly. For example, for x=200-250 m there was significant erosion/accretion owing to bar migration during the experiment, thus an object on the seafloor in this region would become more deeply buried. These data resulted in a value of P that was large, ie, even with bedforms migrating past the object, the object was buried 45-75% of the time after 16 days. In addition, this condition was reached quickly, after only 8 days. In deeper water (x > 250 m in Fig 4), less energy reaches the seafloor and D_{max} (not shown) and P are smaller and their temporal development occurs more slowly (only 16% burial after 8 days and only 35% burial after 16 days). As this study progresses, the relationships bewteen D_{max}, P, wave energy, water depth and time will be quantified to be used as predictive tools.

IMPACT/APPLICATION

The threat of mines has an enormous impact on Naval operations. Methods exist for search and identification of proud mines, but the potential existance of buried mines is of considerable concern. This work will help to describe the process of mine burial by bottom bedform movement, and will quantify the expected time scales, probabilities and depths of burial in the nearshore.

TRANSITIONS

This work has not yet lead to any transitions.

RELATED PROJECTS

This work is part of the Mine Burial Program, a coordinated effort to study all processes of mine burial including impact and scour burial.

REFERENCES

Gallagher, E.L., S. Elgar, and R.T. Guza (1998a) Observations of sand bar evolution on a natural beach, *J. Geophysical Research*, 103, 3203--3215.

Gallagher, E.L., Elgar, S., and Thornton, E.B. (1998b) Megaripple migration in a natural surf zone. *Nature*, 394, 165-168.

Gallagher, E.L., E.B. Thornton and T.P. Stanton (2003) Sand bed roughness in the nearshore, *J. Geophysical Research*, 108(C2), 3039.

PUBLICATIONS

Gallagher, E.L., E.B. Thornton and T.P. Stanton (2003) Sand bed roughness in the nearshore, *J. Geophysical Research*, 108(C2), 3039.

Gallagher, E.L. (2003) A note on megaripples in the surf zone: evidence for their relation to steady flow dunes, *Marine Geology*, 193, 171-176.